Rocky Mountains Southwest Great Plains

Research Note RM-463

February 1986

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Comparison of Forest Floor Depth to Loading Relationships from Several Arizona Ponderosa Pine Stands

Michael G. Harrington[1]

The forest floor depth to loading relationship of a southeastern Arizona ponderosa pine stand was developed for use in general fuel loading assessments. A comparison of this relationship with those from other Arizona ponderosa pine stands revealed some large differences. Therefore, users are cautioned about the widespread application of individual depth to loading relationships.

Keywords: *Pinus ponderosa*, forest fuels, fire management

Management Implications

Forest floor depth to loading regression equations, if properly applied, can be useful in fuel assessment. This study compared four regressions developed in different ponderosa pine stands in Arizona. Average forest floor loadings varied; but more important, bulk densities differed, ranging from about 6.5 tons per acre-inch to 18.0 tons per acre-inch. Some of the differences resulted from inclusion or exclusion of woody fuels from the forest floor samples, or the inclusion of different sizes of woody fuels. Site characteristic differences and dissimilar types and frequencies of disturbances were the most likely reasons for basic bulk density diversity and, therefore, variation between regressions.

Fuels management decisions are based primarily on quantities and types of fuels present. If an improper forest floor depth to loading regression is used, fuel loading will be incorrectly estimated. This presumably could lead to erroneous conclusions, and may result in failure to meet management objectives or unforeseen site damage if prescribed fire is applied.

[1]*Research Forester, Rocky Mountain Forest and Range Experiment Station. Headquarters is in Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University.*

Introduction

Dead organic matter resting on mineral soil can noticeably impact the physical, chemical, and biological functions of a particular site. The quantities of this layer of organic matter or forest floor can affect understory vegetation (Clary et al. 1968), moisture regimes (Aldon 1968), tree reproduction (Pearson 1950), soil nitrogen (Moir 1966), herbaceous species composition (Pase 1958), microbial populations (Harvey et al. 1979), erosion (Rothacher and Lopushinsky 1974), and soil temperatures (Fowler 1974). Amounts of forest floor material are also important for determining potential fire behavior and fire effects (Martin et al. 1979).

Direct measurements of forest floor weights are difficult and time-consuming, because many samples must be extracted, bagged, oven-dried, weighed, and frequently separated from incorporated inorganic material (Sackett 1979). Attempts have been made to develop relationships between readily available stand characteristics and forest floor loadings (weight per unit area) to allow simpler methods for acquiring necessary fuel information. Some of these have been successful (Dieterich 1963, McNab et al. 1978); others have failed to produce usable relationships (Brown 1966, Ffolliott et al. 1968). Forest floor depth is another variable known to be directly related to forest floor loading (Williston 1965, Woodard

and Martin 1980). This relationship, once established, makes it easier to measure depths and calculate weights, compared to measuring weights directly.

Even when depth to loading relationships are developed for one or more forest stands, their applicability to similar sites is uncertain. The purposes of this study were (1) to determine if a valid correlation exists between forest floor depths and unit area weights in a ponderosa pine (*Pinus ponderosa* vars. *scopulorum* and *Arizonica*) stand in southern Arizona, and (2) to compare this relationship with those developed in other Arizona ponderosa pine stands.

Study Site

The study area is in the Santa Catalina Mountains, on the Coronado National Forest, in southeastern Arizona. Three sites were chosen for sampling, each representative of the undisturbed, uneven-aged stands of ponderosa pine in this mountain range. All sites are on southwest aspects and 30–50% slopes, at elevations ranging from 8,000 to 8,500 feet. The sites are about 0.5 mile apart; therefore, all are influenced by similar weather conditions including average annual precipitation of 30 inches. None of the sites had experienced cutting treatments, and fires had not burned there for about 70 years. Stand characteristics for the three sites ranged from 1,600 to 2,300 trees per acre and 190 to 240 square feet of basal area per acre.

Methods

A series of plots, from which forest floor samples were collected, were randomly established in each of the three sites. Homogeneity of vegetation and lack of disturbance were essential in site selection. The number of plots at each site differed, because the size of each site varied as a result of adjacent vegetation changes. Within the three sites, 18, 9, and 16 plots were established.

Each plot consisted of a nonrandom 3 by 3 grid with each of the 9 points spaced 20 to 25 feet apart. At each point, all forest floor material above mineral soil and up to 1 inch in diameter was collected within a 1-square-foot sampling frame; the material was bagged and returned to the lab for oven-dry weight determination. In addition, four forest floor depth measurements were taken at the midpoint of each side of the square foot sample. These four values were averaged to get a single depth for each sample point. Plot averages were determined for both depth and weight per area by calculating the means of the nine samples in each plot. The forest floor weights per area were then regressed against depths, and a series of curves were fitted to the data to find the best relationship.

Results

The average depth and loading of the forest floor was 3.0 ± 1.2 inches and 28.7 ± 11.1 tons per acre, respectively. This loading is quite heavy compared to an average of 12.7 tons per acre measured in a comprehensive study of 62 southwestern ponderosa pine stands (Sackett 1979). The ample forest floor in the present study probably resulted from high site productivity, fairly dense stands, and lack of disturbance for over 65 years. The mean forest floor bulk density has 9.5 tons per acre-inch. In comparison, Brown (1970) reported average forest floor densities for 13 ponderosa pine stands in Montana to be 5.9 tons per acre-inch, whereas Agee (1973) found densities in California ponderosa pine-incense cedar (*Libocedrus decurrens*) stands to range from 7.9 to 10.2 tons per acre-inch.

Figure 1 shows the forest floor depth to loading regression with designation of the three sites. The correlation is quite good, with 78% of the loading variation explained by depth variation. The remainder of the variation could not be accounted for by distinct stand characteristics such as basal area, tree density, or time since last fire disturbance. Fire-scar analysis indicated that the most recent fires burned each site at approximately the same time, 65 to 70 years ago. Any difference in severity of the last fires on each site cannot be judged, because stand characteristics are similar.

Other studies of forest floor depth, loading, and bulk density have been conducted in three different ponderosa pine stands in Arizona. Ffolliott et al. (1968) found depths and loadings under stands in northern Arizona averaged 1.3 ± 0.1 inches and 9.3 ± 0.8 tons per acre, respectively; while Ffolliott et al. (1976) measured a mean depth of 1.0 ± 0.3 inch and loading of 7.0 ± 3.6 tons per acre in east-central Arizona. Eakle and Wagle (1979) reported an average depth and loading on three eastern Arizona ponderosa pine sites of 1.0 ± 0.7 inch and 17.3 ± 13.4 tons per acre, respectively. This loading is substantially more than the two previously noted studies, but still less than the 28.7 tons per acre measured in the present study. Some of the differences can be accounted for by dissimilar sampling techniques. In the north and east-central studies, only needles and their derivatives were collected, while in the eastern study all organic matter up to 2 inches in diameter was sampled. In the present study, all forest floor material up to 1 inch was included, with woody fuels averaging 8% of the total forest floor weight. Sackett (1979) found that the forest floor on 62 southwestern ponderosa pine stands was composed of a similar percentage of less than 1-inch diameter woody fuels. Therefore, if this percentage of woody fuels is assumed to occur on the sites studied by Ffolliott et al. (1968) and Ffolliott et al. (1976) and is added to the needle fuel loadings, then for approximate comparability, the forest floor loadings of these sites including woody fuels up to 1 inch in diameter would increase to about 10.1 and 7.6 tons per acre, respectively. These values are still well below that of the present study. Logging disturbance within 10 to 15 years of the studies likely resulted in these modest loadings. Even though Eakle and Wagle's (1979) samples included woody material up to 2 inches in diameter, they reported that few twigs greater than 0.25 inch were collected. Consequently, their reported loadings should be directly comparable to those of the present study.

For fuel weight estimations using depth measurements, the bulk density of the forest floor must be known. Ffolliott et al. (1968) found the loading per depth of needle fuels at the northern site to be 6.0 tons per acre-inch, which would be approximately 6.5 tons per acre-inch if woody fuels up to 1 inch were included as before. The forest floor bulk density at the east-central site was 8.0 tons per acre-inch (Ffolliott et al. 1976), corrected to about 8.7 tons per acre-inch with the addition of woody fuels. If mean densities of the forest floor horizons designated by Eakle and Wagle (1979) are summed, average bulk densities for the eastern site would equal 18.0 tons per acre-inch. These bulk density values vary slightly to considerably from each other and the 9.5 tons per acre-inch measured in the present study.

Figure 2 compares the forest floor depth to loading regressions for the four Arizona ponderosa pine sites investigated. The eastern site relationship was developed by plotting a series of depths within the data range along with computed loadings, which are the sums of the proportions found in each distinct forest floor layer. Three of the regressions are linear, while the eastern site produced a logarithmic relationship, which still approximates linearity. This linear nature indicates that over the range of the data, the bulk density within each study remains fairly constant. Although the slopes cannot be statistically compared, obvious dissimilarities exist. Much greater quantities of forest floor were found at any depth on the eastern site than on the other three sites. In the present study (southern site), loadings per depth were similar to those found at the east-central site, and both contained larger quantities of forest floor fuels than the northern site.

Another obvious difference is in the range of the data indicated by the length of the regression line (fig,. 2). The three previously reported studies had numerous depth measurements at or near 0 inch. Because the present study site had few depths less than 2.0 inches, it would be inappropriate to extend the regression to the origin.

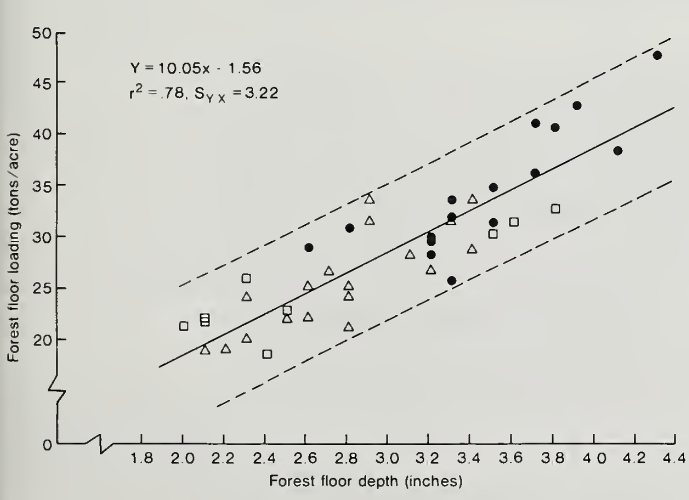

Figure 1.—Forest floor depth to loading regression for three stands in southern Arizona. The three symbols represent sample points from the three stands examined. Dashed lines are the 95% confidence limits.

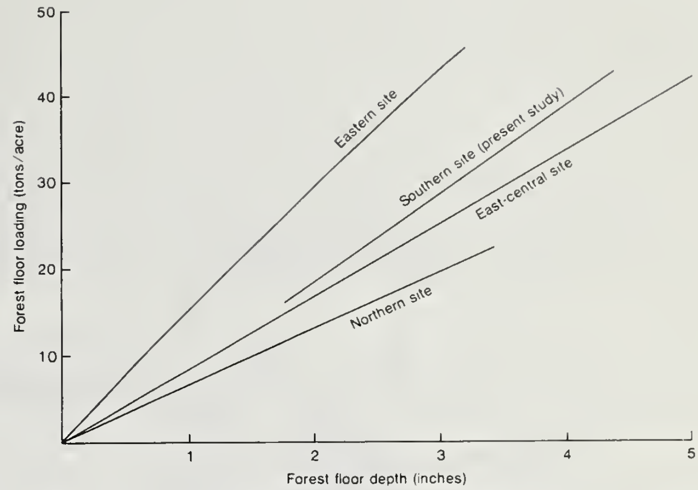

Figure 2.—Comparison of the forest floor depth to loading regressions from the four Arizona sites.

However, forest floor depths greater than 3.0 inches were quite rare in the eastern and northern sites, whereas the average depth at the present study site was 3.0 inches. The east-central site had the greatest range of depth; but most of these were less than 2.0 inches.

Discussion

To assess potential fire behavior and estimate possible fire effects, the quantities and types of fuels to be burned should be known (Brown 1970). Brown's (1974) planar intercept method is commonly used to determine woody fuel loading and fuel and duff depths, primarily in areas with activity slash. On sites with enough forest floor needle material to influence fire behavior and effects, loading of this fuel type also should be known. Because forest floor depth are measured in the planar intercept method, a depth to loading relationship could be used to provide this fuel weight.

If the use of forest floor depth to loading relationships is proposed, it is important to know how applicable these relationships are to diverse sites. The comparisons made in this note indicate that caution should be used in widespread application of these relationships. Various stands of the same species in adjacent forests can have not only obvious differences in forest floor loadings, but also fairly large, yet less evident, differences in bulk densities. These dissimilarities can be the result of variations in climate, soils, stand characteristics (including age), biomass production rates, needle deposition rates, decomposition rates, and types and frequencies of stand disturbances (fire, logging, etc.). If bulk density differences exist between sites of its measurement and sites of its use for loading estimation, then fuel loadings will be inaccurately predicted.

Another possible problem in applying forest floor depth to loading relationship could arise if the specific fuel classes included in the development of this relationship are not recognized. For example, Ffolliott et al. (1968, 1976) sampled only needle fuels, and their regres-

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526